and to study the effects of aging on the physical properties of these materials. There is also a need for experiments to measure fundamental nuclear physics properties using plutonium or highly enriched uranium that require ignition.

- There is a need to perform experiments on the NIF with lithium hydride, which is not a special nuclear material, with and without ignition. These are materials physics and equation of state experiments designed to address fundamental physical behavior of this material and to allow benchmarking of physical models of the material.
- There is a need to perform experiments on the NIF with depleted uranium with ignition. These experiments require high atomic number materials collocated on the ignition target to enhance the conversion of laser light to x-rays for inertial confinement fusion experiments. There is also a need for experiments that use depleted uranium or highly enriched uranium with ignition to study the physics of these materials.
- There is a need to perform experiments on the NIF with fissionable materials, e.g., thorium-232, and fissile materials, e.g., highly enriched uranium, with ignition. These experiments require the materials to be collocated on the ignition target to provide a measurement of the nuclear processes that occur in an ignition capsule.

There is no NNSA proposal for using a neutron multiplying assembly for experiments on the NIF (Crandall 2002).

The use of special nuclear material on the NIF would allow weapons scientists to accurately evaluate the properties of special nuclear material in the laboratory and to validate weapons test data and refine computer codes to reduce uncertainties.

M.3 DESCRIPTION OF THE NO ACTION ALTERNATIVE, PROPOSED ACTION, AND REDUCED OPERATION ALTERNATIVE

The construction of the NIF conventional facilities is complete and installation of the laser, diagnostic equipment, and target area equipment is in progress. Experiments on the NIF for stockpile stewardship have begun and will continue in parallel with the completion of installation and commissioning of the 192 beam lines. The NIF will transition into full operation following the approval of Critical Decision 4, scheduled to occur in 2008. *National Environmental Policy Act* (NEPA) compliance for conventional facility construction and equipment installation of the NIF is described in the NIF project-specific analysis of the SSM PEIS (DOE 1996a) and was amended by the Supplement Analysis for the use of Hazardous Materials in the NIF Experiments (DOE 1998c) and the Supplemental SSM PEIS (DOE 2001f).

This appendix analyzes the No Action Alternative, Proposed Action, and Reduced Operation Alternative for the NIF. Section M.3 is broken into subsections as follows:

- M.3.1 covers the No Action Alternative, which includes the NIF experiments and operations for which decisions have already been made and provides information on the hazardous and radioactive materials approved for use on the NIF.
- M.3.2 covers the Proposed Action for changes in NIF operations; the use of plutonium, other fissile materials, fissionable materials, and lithium hydride in experiments on the NIF; and the construction and operation of a neutron spectrometer.
- M.3.3 evaluates the Reduced Operation Alternative for the NIF.

- M.3.4 provides a summary and comparison of the environmental impacts of the No Action Alternative, Proposed Action, and Reduced Operation Alternative.

Table M.3–1 summarizes the differences in the operating parameters of the Proposed Action and alternatives.

The data for this appendix were taken mainly from two documents: the SSM PEIS, Volume III, Appendix I (DOE 1996a) and the *NIF Project Input for Assessment of Environmental Impacts of the NIF* (LLNL 2003d).

TABLE M.3–1.—*National Ignition Facility Operating Parameters for Each Alternative*

	No Action Alternative	Proposed Action	Reduced Operation Alternative
Laser energy	1.8 MJ, 192 beams	1.8 MJ, 192 beams	1.8 MJ, 192 beams
Yield, maximum	20 MJ[a]	20 MJ[a]	20 MJ[a]
Total	1,200 MJ/yr	1,200 MJ/yr	800 MJ/yr
Tritium throughput,	1,750 Ci/yr	1,750 Ci/yr	1,500 Ci/yr
Inventory in process,	500 Ci	500 Ci	500 Ci
Plutonium	No	Yield and non-yield experiments	No
Fissile material use	No	Yield and non-yield experiments	No
Fissionable material use	Only non-yield depleted uranium	Yield and non-yield experiments	Only non-yield depleted uranium
LiH	No	Yield and non-yield experiments	No
Neutron spectrometer	No	Yes	No
Removable inner containment vessel	No	Yes	No
Facility hazards category	Low-hazard, radiological	Low-hazard, radiological	Low-hazard, radiological

Source: LLNL 2003d.
[a]45 MJ maximum credible yield per experiment.
Ci = curie; LiH = lithium hydride; MJ = megajoules; yr = year.

M.3.1 No Action Alternative

The No Action Alternative comprises the continued installation of equipment and operation of the NIF. Under the No Action Alternative, the NIF would be operated under the parameters described in the SSM PEIS NIF project specific analysis and summarized in Table M.3–1. The NIF would perform the full ignition program required to meet SSP goals but would not perform experiments with plutonium, other fissile materials, fissionable materials (other than depleted uranium), or lithium hydride. The neutron spectrometer would not be constructed. The NIF would be operated as a low-hazard radiological facility.

This section expands on the basic information provided in Section M.1.2 and provides an overview of the experiments and operation of the NIF. Information is provided on the use of resources and materials under the No Action Alternative. The manner of operation of the NIF laser and target area building and the laser system would basically be the same for all of the alternatives and will not be repeated in the Proposed Action and the Reduced Operation Alternative sections. The level of operation (number of experiments) and the quantity of materials used would vary among No Action Alternative, Proposed Action, and Reduced Operation Alternative.

The NIF consists of three main elements housed in the laser and target area building, a single environmentally controlled building. The elements of the NIF are the laser system and optical components, a target chamber placed within a target bay, and an integrated computer system to control the laser and diagnostic equipment. The following sections cover the operation and hazards associated with the NIF laser and target area building (Section M.3.1.1), the laser system (Section M.3.1.2), the target chamber and target area (Section M.3.1.3), and NIF experiments (Section M.3.1.4). Section M.3.1.5 discusses hazardous material use in NIF operations, and Section M.3.1.6 covers facility decontamination and decommissioning (D&D).

The computer control system is an integrated network of computer systems providing the hardware and software needed to support full operational activities. The system includes the computer controls to manage the laser optical system, target system, and data acquisition. Information on the computer control system is not addressed in this appendix. Certain control systems, such as the safety interlock system, are presented where pertinent to the discussion of environmental impacts and accidents.

M.3.1.1 *National Ignition Facility Operations*

The laser and target area building is a reinforced concrete and structural steel building constructed to be vibration isolated, provide radiation confinement and control, and include all necessary system control and diagnostics. It consists of two laser bays, two optical switchyards, a target chamber in a shielded target bay, target diagnostic areas, four capacitor bays, mechanical equipment areas, control rooms, and an operational support area (Figure M.1.2–1).

The laser bays are steel-framed, metal-sided rooms with a metal deck roof and steel-reinforced concrete floor. Each laser bay houses 96 individual laser beam lines. The capacitor bays are four separate rooms that house the power conditioning system used to operate the main laser amplifiers. Capacitor bay equipment includes capacitors, spark-gap electrical switches, and power conditioning equipment. The power for the NIF laser would be supplied by discharging the bank of capacitors. The capacitors would be charged using electricity supplied from the LLNL utility system.

The two optical switchyards house optical systems, that is, mirrors and beam tubes, that direct and position the 192 laser beams into the target bay and target chamber. The switchyards are constructed of steel-reinforced concrete.

The diagnostic building, adjacent to the target bay, houses the environmental protection systems, target receiving area, tritium processing area, and diagnostic support areas. The tritium processing system would operate by oxidizing gaseous tritium and capturing the oxidized tritiated water on molecular sieves. The tritium processing system molecular sieve canisters would be replaced periodically. The preheater reactor and metal bellows pump would be replaced infrequently (on the order of every 10 years).

Facility Utility Usage

Facility operations would require the use of electrical power, water, and natural gas, and would discharge wastewater. The NIF would use electricity to operate the laser and plant equipment necessary to support basic operations. This would include operations of the heating, ventilation, and air conditioning system (HVAC), chilled and heated water systems, lighting, facility heating, etc. The clean-room high-efficiency particulate air (HEPA) filters clean the supply air going into the building.

Water would be used at the NIF for a variety of operations, including boilers, cooling towers, domestic use, landscape irrigation, washing, and fire hydrant testing. Some of the water would be evaporated to the atmosphere, while other water would be discharged to the sanitary sewer or storm drain, as appropriate. More details concerning projected water use and discharge quantities for the NIF are provided in Section M.5.

The NIF has two standby diesel generators; one is 754 horsepower and the other is 250 horsepower. In the event of a power outage, these generators would operate until the utility power is restored.

M.3.1.2 *Laser Operations*

The NIF laser system would generate and deliver high-power optical pulses to a target suspended in the target chamber. Multiple laser beams would be used to uniformly illuminate the target surface area. The NIF laser contains 192 independent laser beams, or beamlets. Each laser bay houses twelve bundles. Each bundle is made up of two quads of four individual beamlets. Each quad has a unique beam path, or beamline, to the target chamber. The 192 beamlets require more than 10,000 discrete optical components. The laser requires all optical components to be enclosed in a controlled beam tube that is under a vacuum or filled with an inert gas (argon) or a clean gas system of an oxygen/nitrogen gas mixture. The clean gas system provides backfill gas for the amplifiers and beam transport system portions of the laser. Argon is provided to the beam transport system in the switchyard and target bay.

The operating parameters established for NIF experiments are indicated below.

- Laser power/energy to the target: 500 terrawatts/1.8 megajoules
- Maximum design yield per experiment: 20 megajoules (maximum credible yield would be 45 megajoules)
- Annual total yield: 1,200 megajoules per year

M.3.1.3 *Target Bay and Target Chamber*

Target Bay

The target bay houses the following major subsystems: target chamber, target emplacement positioner, cryogenic target positioner, target diagnostics, support structures, environmental protection, and vacuum and other auxiliary systems. The target bay is a steel reinforced concrete cylindrical structure that houses the target chamber. The steel reinforced concrete would provide initial shielding of radiation produced during yield experiments.

The target bay also would provide radiation confinement in conjunction with the HVAC system for radioactive air emissions, such as activated air created during high-yield experiments or a tritium release. The exhaust would discharge from an elevated release point. The exhaust air would be continually monitored to ensure detection of activated material.

Environmental protection systems, including tritium-handling systems, target storage, and decontamination equipment used to clean the target chamber components, will be located in the decontamination area adjacent to the target bay. X-ray, optical, and neutron measurement instruments would be arranged around the chamber to help evaluate the success of each target experiment. Structural support of the target diagnostics, the target positioner, final optic assemblies, and turning mirrors, would be provided by target area structures. The target area would also provide the following subsystems: the target area auxiliary systems, material handling, the target chamber boom lift, and the diagnostics and control rooms.

The NIF shielding design consists of several components. The basic components include the target chamber borated concrete shielding; target bay walls that are 1.83-meter-thick concrete; target bay roof that is 1.37-meter-thick concrete; switchyard walls that are up to 1.14-meter-thick concrete depending upon the specific location, and switchyard roofs that are 0.46-meter-thick concrete. Due to the large number of penetrations through the target bay walls, additional shielding components have been added. These include mechanical equipment room walls that are 0.31-meter-thick concrete; HVAC collimators, concrete tubes that allow airflow to pass while restricting neutrons and gamma-rays; and switchyard collimators 1.83-meter-long extensions of the target bay walls on the switchyard side of the walls.

Target Chamber

The NIF target chamber is a 10-meter internal-diameter spherical aluminum alloy shell with 10-centimeter thick walls. The exterior of the chamber is encased in 40 centimeters of borated concrete to provide neutron shielding. Each of the four beamlets in the target chamber would provide the primary confinement for target experiments. The target chamber is supported vertically by a hollow concrete pedestal and horizontally by radial joints connected to the cantilevered floors. The laser beams would enter the chamber in two conical arrays from the top and two conical arrays from the bottom. At the poles and in the equatorial regions of the chamber, diagnostic equipment would be inserted through the chamber wall. The target chamber would also include the target emplacement and positioning/alignment system.

The laser beams would enter through laser optics, e.g., glass lenses, frequency conversion crystals, and other optics, called the final optics assembly that would be attached to the end of each beam line as it enters the target chamber. Each of the four beamlets in the final optics assembly would be protected from damage by a main debris shield and a disposable debris shield. There would be an ongoing waste stream of solid low-level waste (LLW) from replacement of the disposable debris shields. Some of the main debris shields would require periodic cleaning and could require replacement and disposal due to damage.

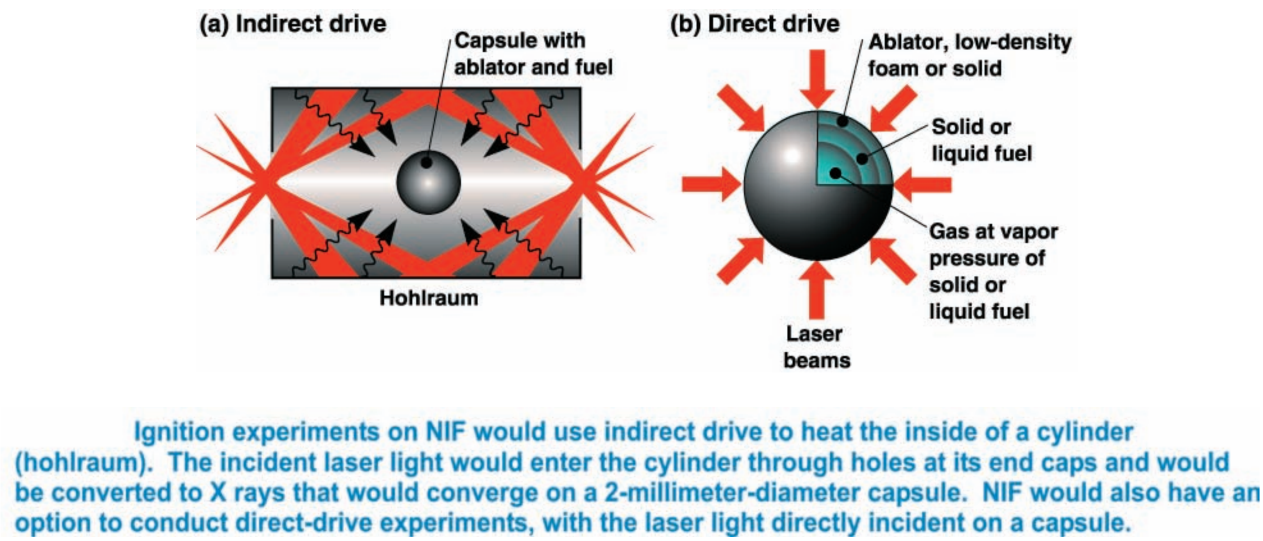
Laser light would leave the final optics assembly and illuminate the target at the center of the chamber. The diagnostics would capture the required data. Light that is not absorbed by the target would continue towards the opposite wall of the target chamber. Just before hitting the target chamber wall, unconverted laser light that hits the opposite wall would be absorbed by the light-absorbing stainless steel first wall panels located opposite of each beam port. The first wall panels, which would also provide protection of the target chamber from debris and soft x-rays, would require periodic replacement due to wear, damage, and/or chemical contamination. It is anticipated that the panels would be cleaned once per year and replaced once every eight years, resulting in solid radioactive LLW.

The components used in target chamber diagnostics could be damaged during higher yield experiments and become a solid LLW stream. Filters would process the target chamber air exhaust. Charcoal filters would also be used to capture certain isotopes, and these would need periodic, but infrequent replacement. There will be two high-efficiency particulate air filters and two prefilters controlling the emissions from the target chamber. There would be approximately 20 additional HEPA filters with local area control applications. A change out schedule of at least once every 10 years would be required by LLNL. Filter disposal would generate solid LLW.

M.3.1.4 *National Ignition Facility Experiments*

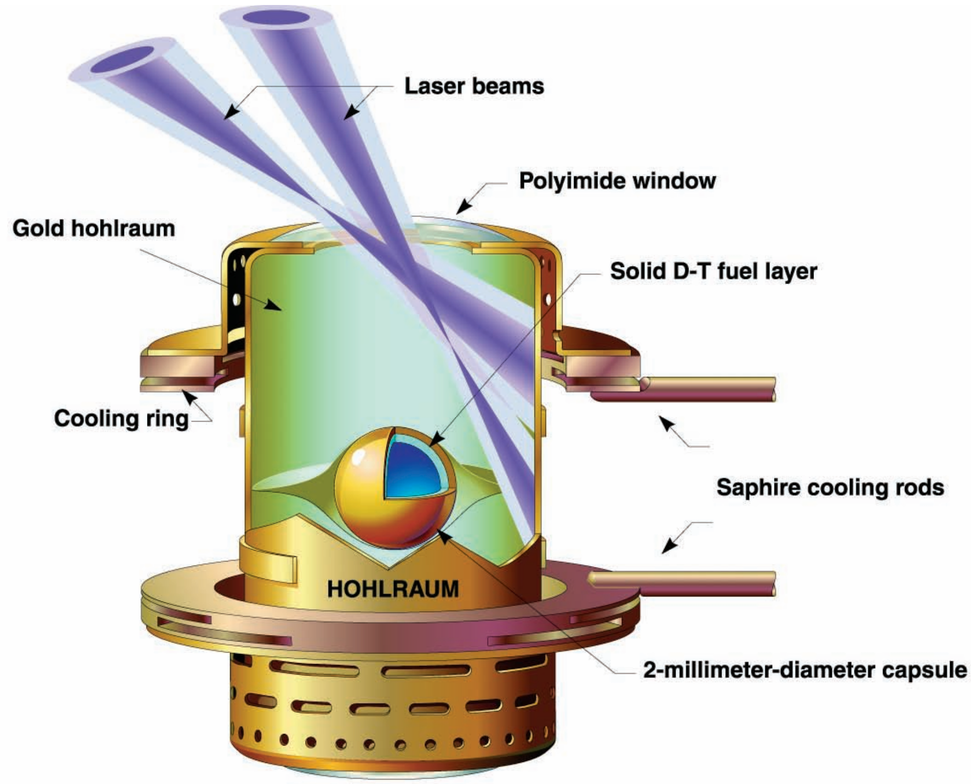
Both indirect-drive and direct-drive experiments could be conducted on the NIF, as illustrated in (Figure M.3.1.4–1). Initial operation of the NIF would use indirect-drive experiments where x-rays generated by the interaction of the laser beams with a small metal cylinder or hohlraum would cause the compression of the target (Figure M.3.1.4–2). The first ignition experiment for NIF is planned for 2010.

Direct-drive experiments could also be conducted on the NIF. With direct drive, the laser beam, rather than x-rays, would directly compress the target. When the laser fires on an ignition target, all 192 beams would be synchronized and simultaneously illuminate the target. The target would be compressed and heated, creating intense fusion reactions. The direct-drive mode was discussed as part of the SSM PEIS.



Source: LLNL 1999k.

FIGURE M.3.1.4–1.—*Indirect- and Direct-Drive Experiment Modes*



Source: LLNL File Photo LLNL-05-00-0798-162.

FIGURE M.3.1.4–2.— *Schematic View of Hohlraum*

Radiation Produced from Fusion Experiments

Indirect-drive and direct-drive yield experiments using deuterium and tritium would emit neutrons, energetic particles, debris, and x-rays. The energetic particles, debris, and x-rays would be confined within the aluminum alloy target chamber. Most neutrons and secondary radiation from a yield experiment would travel through the target chamber and its surface shielding layer before being adequately attenuated by target bay structures and concrete walls. Some neutrons would activate target bay structures, including the target chamber, shielding, space frame, optics, beam tubes, catwalks, and reinforced concrete walls.

Tasks that must be performed within the target bay or that involve handling of materials that have been inside the target bay during experiments would result in some level of radiation dose. Dose rates within the target bay would be largely dependent on the yield of the most recent experiment and the amount of time since the experiment took place. The residual radiation intensity within the target bay at any particular location would depend upon local and general activation in the room as well as the history of yield experiments.

Neutrons would penetrate through the roof of the facility and cause skyshine radiation, where the neutrons scatter (reflect) off of the atmosphere above the facility and scatter back down to the ground. Some neutrons would interact with structural material and emit gamma rays as they undergo nuclear reactions, and these gamma rays would also reach the ground.

Tritium

Tritium would arrive at the facility in individual targets, containing up to 5 curies each; 2 curies in the capsule and up to 3 curies in the associated hardware. If direct drive is implemented, each target would contain up to 70 curies. The annual tritium throughput at the NIF would be limited to 1,750 curies per year.

Tritium could be in process in various locations at the NIF, but would remain below the 500 curies total in-process inventory limit. The total in-process tritium inventory would include any accumulation of tritium in the facility that is releasable and quantifiable, and that is part of the tritium handling cycle in the NIF. This would include inventories in locations such as targets and associated hardware, cryopumps, molecular sieve traps, and decontamination systems. It would not include residual surface contamination and adsorption. Therefore, the tritium adsorbed on the target chamber walls after an experiment would not be part of the in-process inventory.

Particulates

Particulates would be generated in the target chamber from each experiment. During an experiment, the laser energy would vaporize the target. Reflected or unused laser light is absorbed on the protective first wall panels and would induce ablation of this surface, with the loss of mass from the surface of the wall panels by vaporization or as small molten droplets. The emission of x-rays from the experiment could be sufficiently high to induce yet further ablation from nearby equipment surfaces, protective first wall panels, and debris shields. Structures close to the target could undergo melting during high yield experiments. The state of the ablated material after an experiment is expected to be small pieces of debris and fine particulates. For the purpose of this analysis, it was conservatively assumed that all the ablated material would exist as fine particulates about one micron in size; i.e., most easily made airborne and in the respirable range.

As the particulate material is exposed to neutrons from yield experiments, some material would become activated and converted to radioactive material. The particulates would accumulate in the target chamber until the scheduled annual cleanup. The total inventory of activated, mobilizable particulates created in the chamber would be quite small. A list of the prominent nuclides that would be expected as activated particulate in the chamber, room air, and in beam tubes is presented in Section M.5.

M.3.1.5 *Hazardous Materials*

Materials needed to support NIF operations would include inert gases (argon) for laser operations, nitrogen for cryopumps, and other chemicals for cleaning, decontamination, and general use. Some of these materials would be regularly consumed; others could be expended and require replacement during the lifetime of the NIF. There would be no explosives stored or used at the NIF.

The NIF would use volatile organic solvents for lens cleaning and other wipe cleaning operations in the clean room environment. These would include ethanol, acetone and isopropanol. The main agent currently used (Brulin 815 GD) contains no hazardous ingredients, according to its material safety data sheet, and is generally approved for discharge to the sewer. The usage of solvents for wipe cleaning has been greatly reduced by using dilute aqueous solvent solutions, steam cleaning, dry wiping, and other techniques. Other chemicals would be stored in small quantities at the facility. Acetone and ethanol are used only for occasional spot cleaning. Clean room wipes presaturated with 9 percent isopropanol in de-ionized water would be used more frequently, but also in small quantities.

Decontamination processes require a working inventory of cleaning agents. An onsite inventory to replenish working solutions is also needed. This includes phosphoric acid, nitric acid, and sodium hydroxide. These will be utilized in cleaning solutions in the decontamination area.

The power conditioning units used in support of the preamplifier modules would have sets of ignitron switches, which would contain mercury. Each of the 48 preamplifier modules would have a dedicated, closed ethylene glycol/deionized-demineralized water coolant loop for thermal control.

The NIF would handle small quantities of beryllium in the form of targets, up to 1.6 grams per year, and in diagnostic windows. The NIF would use beryllium in two forms: protected collected solids, primarily in filters, that cannot become particulate, and material in exposed diagnostics and targets that can become particulate. It is not anticipated that there would be significant airborne exposure to workers. This will be confirmed by air monitoring. Surface swiping would be performed to confirm that surface beryllium contamination remains within permissible housekeeping limits for beryllium work areas (10 CFR Part 850).

Targets and hohlraums would be made of components that could include small quantities of hazardous and toxic materials including beryllium, lead, dysprosium, gadolinium, germanium, scandium, silicon, tantalum, and titanium. During an experiment, energy, through either indirect drive with a hohlraum or direct drive, would be deposited on the target resulting in the general vaporization of the target and hohlraum. The debris from the target and hohlraum would be deposited on the target chamber wall and debris shields. Some debris could take the form of particulates (see Section M.3.1.4.3). This appendix assumes that the target chamber would only be decontaminated once per year, to conservatively bound the amount of activated particulates and worker exposure. The actual schedule for decontamination of the target chamber would be managed according to the schedule of experiments, the amount of materials in the target chamber, and the risks to decontamination workers. Decontamination of the target chamber would be performed in accordance with radioactive and hazardous material handling procedures appropriate to the content of the material in the chamber at the time of the decontamination.

M.3.1.6 *Decontamination and Decommissioning of Facilities*

A D&D plan was developed for the NIF during design of the facility and was updated in 2001 (LLNL/NIF 2001). The plan outlines the D&D planning activities and describes general assumptions about the facility including components and their projected status or disposition at the facility end of life. The main purpose of the plan was not to project waste amounts, but to ensure that the decommissioning could be easily accomplished and to examine design features that could facilitate the eventual D&D of the NIF. The NIF is assumed to operate for 30 years. The D&D of the laser would involve the reuse or salvage of materials, storage of research materials for later experiments in follow-on facilities, and disposition. Most of the waste would be industrial waste.

Cleanup of the NIF target area is expected to generate a total of 263 cubic meters of LLW waste (including the shipping containers) and 226 cubic meters of hazardous waste (LLNL/NIF 2001). Following D&D of the building, it would be returned back to the institution for further use. Useful building utilities, conventional lighting, water, etc., will remain in place. D&D of the neutron spectrometer would produce another 30 cubic meters of hazardous waste.

M.3.2 Proposed Action

The Proposed Action section discusses the additions to NIF operations that would result from the proposed use of plutonium, other fissile materials, fissionable materials, and lithium hydride in experiments on the NIF. These experiments, as well as the operation of the NIF, would have a design lifetime of 30 years. For this discussion the materials considered are: fissile materials; i.e., materials that fission when irradiated by slow or thermal neutrons; such as uranium-235 or plutonium-239, and fissionable materials, i.e., materials that can be induced to fission by fast neutrons such as uranium-238 (depleted uranium) or thorium-232. The specific fissile/fissionable materials (beyond depleted uranium) considered for the Proposed Action would be weapons grade plutonium[2], highly enriched uranium[3], and thorium-232. Weapons grade plutonium experiments would be performed using an additional inner containment vessel (see Section M.3.2.1) to protect the target chamber. It is estimated that there would be a maximum of four yield experiments (with plutonium) per year, at fusion yields up to 45 megajoules, and 10 non-yield plutonium experiments per year with inner containment. If other fissile materials were required for NIF experiments the inventories of these materials would be limited such that their environmental impact, such as offsite accidents, worker exposure, etc., would not exceed the bounds defined in this document. Yield experiments and non-yield experiments with highly enriched uranium, thorium-232, and other fissionable materials would most likely be performed in the NIF target chamber without additional containment. Experiments with small quantities of specially prepared plutonium could be used without an inner containment vessel provided the environmental impacts do not exceed the bounds defined in this document. Other materials that would also be used in the Proposed Action at the NIF are beryllium, depleted uranium, and lithium hydride (including lithium deuteride[4]).

In addition, the Proposed Action would include the construction and operation of a neutron spectrometer to more accurately measure neutron yield and diagnose ignition target physics (see Section M.3.2.4).

Section M.3.2.1 discusses the proposed experiments with fissile and fissionable material and changes in the target chamber operations and related information. Section M.3.2.2 covers transportation of materials, and Section M.3.2.3 covers waste generation. Section M.3.2.4 covers the construction and operation of a neutron spectrometer.

The experiments under the Proposed Action involving the use of plutonium, other fissile materials, fissionable materials, and lithium hydride in targets would be in addition to the types of experiments that would take place under the No Action Alternative. The basic operation of the facility, the laser, the target area, and eventual D&D of the NIF, would not be affected by these

[2] The assumed composition of weapons grade material is 0.02% plutonium-238, 93.85% plutonium-239, 5.8% plutonium-240, 0.3% plutonium-241, 0.015% americium-241, and 0.02% plutonium-242. Other isotopic mixes could be used if their impacts were within the bounds described here.

[3] Highly enriched uranium contains equal or greater than 20% uranium-235.

[4] Lithium deuteride consists of lithium and deuterium, which is the nonradioactive isotope of hydrogen.

additional types of experiments. They would be the same as described for the No Action Alternative. Therefore, only those aspects of operations that would be changed are discussed here.

The inventories used in the analysis in Section M.5 are maximum inventories that would be required for the Proposed Action. The inventories are derived from a final 45-megajoules-yield experiment, ending one year of experiments with 1,200-megajoules total yield. Experiments of this magnitude (45 megajoules) would not be scheduled as part of the normal experimental plan. However, 45 megajoules is the maximum credible yield that could be obtained. The 45-megajoules inventories are used here to bound all inventories of radioactive particulates and fission products. Table M.3.2.1–1 presents the maximum inventory of beryllium, lithium hydride, depleted uranium, plutonium, highly enriched uranium, thorium-232, and tracer elements for the Proposed Action.

TABLE M.3.2.1–1.—*National Ignition Facility Inventories for Proposed Materials*

Material	Maximum Inventory
Beryllium	20 g
Lithium hydride/Lithium deuteride	125 g
Depleted uranium	100 g[a, b]
Plutonium	3 g
Highly enriched uranium[c]	100 g
Thorium-232	450 g
Tracer elements, (iodine is representative)[d]	0.1 g

Source: LLNL 2003d.
[a] The single-experiment inventory limit results from the fission products created during a single high-yield experiment (45 MJ), as well as buildup of the longer-lived fission products during one year of 1,200-MJ operation.
[b] This is the total quantity of depleted uranium that could be in the National Ignition Facility target chamber at any one time. Individual targets for yield experiments would be limited to 2.2 g for depleted uranium.
[c] Assumed composition, by weight, is 93.5 uranium-235, 5.4 % uranium-238, and 1.1 % uranium-234. Individual targets for yield experiments would be limited to 1.2 g for highly enriched uranium.
[d] Other possible tracer elements include: beryllium, lithium, oxygen, neon, chlorine, argon, titanium, chromium nickel, copper, arsenic, bromine, krypton, rubidium, yttrium, zirconium, niobium, molybdenum, rhodium, silver, iodine, xenon, neodymium, samarium, europium, thulium, lutetium hafnium tantalum, tungsten, rhenium, iridium, gold, thallium, bismuth These are bounded by the representative tracer and could be used in similar quantities. The quantity in the table assumes 60 experiments/yr, each at 1.7 mg.
Note: g = gram(s); yr = year.

M.3.2.1 *National Ignition Facility Experiments*

Section M.2.4 discusses the purpose and need for the use of the proposed materials; i.e., plutonium, other fissile materials, fissionable materials, and lithium hydride in NIF experiments. This section describes the types of experiments that would be conducted and the types of materials that would be used in these experiments. The experiments that are being considered include yield experiments and non-yield experiments using any of the proposed materials. These would be bounded by the yield and non-yield experiments with plutonium.

Experiments with depleted uranium, highly enriched uranium, lithium hydride, fissionable materials, fissile uranium, and experiments with small quantities of specially prepared plutonium would occur in the target chamber in the same manner as all other experiments discussed under the No Action Alternative. There would be both yield and non-yield experiments with these materials. Yield experiments with highly enriched uranium and fissionable materials would generate fission products, but negligible plutonium quantities. These experiments would use the same target positioner and similar diagnostics. No new features would have to be added to the NIF or the support facilities to field experiments with these materials. The NIF would be operated as a low-hazard radiological facility under the Proposed Action.

Experiments with an Inner Containment Vessel

For this analysis, a tritium fusion yield experiment with weapons grade plutonium is used as the bounding scenario. Experiments using weapons grade plutonium in the presence of yield create radiological concerns because fission products would be generated and neutron activation of materials could occur. Because most isotopes of plutonium have a much higher activity than highly enriched uranium, depleted uranium, or thorium-232, a separate inner containment vessel fabricated from stainless steel would be used to prevent the weapons grade plutonium and fission products from being deposited on the target chamber, first wall, target positioner, or diagnostics. This inner containment vessel would be assembled at a LLNL support facility and transported to a LLNL facility such as the Tritium Facility for loading. Just prior to a plutonium experiment with inner containment, the target would be inserted into the inner containment vessel and the inner containment vessel would be transported in a shipping container to the NIF as a sealed and assembled unit. The inner containment vessel would be placed into the NIF target chamber through the large port on the target chamber equator or through the bottom of the target chamber.

Seismic requirements for support of the inner containment vessel would require new “hard points” being installed in the target chamber to support the inner containment vessel. The side entry system through the large port on the equator would require a custom built manipulator and installation of tracks from the diagnostics building into the target bay. The tracks would have to be removable to close the shield door for yield experiments. Other systems, such as lifting devices, cryogenic systems, and the liquid helium transfer system, could require modification.

Following the installation of the inner containment vessel and the diagnostic package, the target chamber would be evacuated and the laser fired on target. Deposition of laser energy on the target would result in vaporization of the target, emission of x-rays, the release of neutrons and the fission of the plutonium atoms for yield experiments. Radioactive materials generated from these experiments would include plutonium from the vaporized target, activated particulates from neutron activation, and fission products from the fission of the plutonium used in the experiment. All of these materials would be contained by the inner containment vessel. Additionally, x-rays and unconverted laser light would ablate material from surfaces and components, creating particulates in the inner containment vessel.

Once the experiment is completed and after a suitable waiting period, the inner containment vessel would be removed from the NIF target chamber and returned to a LLNL facility, such as the Tritium Facility, for post-experiment examination, processing, and, if needed, decontamination. Personnel at the NIF would not be exposed to the materials inside the inner containment vessel. The inner containment vessel, having been used in a single experiment, would then be placed in a shipping container, either dismantled or whole, and transported to the Nevada Test Site for disposal as LLW. Because the inner containment vessel would only be used for a single plutonium experiment and then removed from the NIF, the bounding inventories for the yield experiment case would include 1 gram of weapons grade plutonium and the associated fission products and activated particulate. For non-yield experiments, the bounding inventory would be 3 grams of weapons grade plutonium.

Modifications to LLNL Tritium Facility to accept the inner containment vessel would include adding hoisting and rigging equipment to place the inner containment vessel into a special glovebox. This glovebox would be used to retrieve samples from the inner containment vessel and decontaminate and dismantle, as necessary, prior to shipment to the Nevada Test Site.

Personnel Exposure

For most yield and non-yield experiments with weapons grade plutonium, placement of the inner containment vessel into the NIF target chamber and its removal after the experiment would result in worker exposure from the target chamber. During this time, personnel are assumed to be in close proximity to a large, open target chamber port. Because they would have a line-of-sight view to the activated target chamber interior, activated as a result of previous experiment, and the inner containment vessel, they would receive some additional amount of exposure. The exposure would be greater during removal of the inner containment vessel after yield experiments because both the inner containment vessel and the NIF target chamber would be further activated from neutrons released during the experiment.

Post-experiment activities would most likely be conducted at the LLNL Tritium Facility and appropriate protective measures, such as protective clothing and gloveboxes, would be used to prevent plutonium exposure. The post-experiment activities that would be conducted in the Tritium Facility include installation of the inner containment vessel into a large glovebox, access to the interior of the inner containment vessel to retrieve samples, if needed, and decontamination and dismantlement of the inner containment vessel prior to shipment as waste. Worker dose would occur mostly due to exposure to the activated inner containment vessel. The inner containment vessel would become activated only for yield experiments.

The increased dose for the Proposed Action would be largely the result of yield experiments, and would occur during removal of the inner containment vessel and post-experiment processing. Smaller doses are incurred for non-yield experiments (during inner containment vessel placement and removal), and during placement of the inner containment vessel for yield experiments. This additional dose (beyond that of the No Action Alternative) was estimated assuming 4 yield experiments with plutonium at 45 megajoules each and 10 plutonium non-yield experiments per year.

Experiments Without Inner Containment Vessel

Radioactive material generated during these experiments would include neutron-activated radioactive particulates created in the target chamber and any fission products generated during yield experiments with specially prepared plutonium, highly enriched uranium, depleted uranium, or thorium-232. As indicated above, experiments with small quantities of specially prepared plutonium could be conducted without an inner containment vessel. Experiments using specially prepared plutonium would be bounded by those covered in highly enriched uranium experiments under the Proposed Action. These radioactive materials would be transferred to the decontamination systems and waste streams as a result of decontamination of the target chamber components. However, because many of the isotopes have short half-lives, the maximum inventories associated with radioactive particulates would be found in the target chamber shortly after the last experiment and well before cleanup. By the time cleaning occurs or components are removed, the radioactive particulate inventory would have decayed to much smaller quantities.

Releases of activated target bay gases would be unchanged for the Proposed Action; however, some fission products would be created during experiments involving fissile or fissionable materials without an inner containment vessel, and some would be eventually released to the environment as part of normal operations. Many are short-lived and would decay while being held on the cryopumps. Alternately, they could be discharged to the accumulation tank and held until most have decayed. Some longer-lived gaseous fission products, such as krypton-85 (10.7

years half-life), would not have decayed by much when they would likely be released to the environment. Fission products that are solids (very small amounts) would be retained in the target chamber. Other semivolatile fission products, such as iodine isotopes, would be captured on charcoal filters, thereby minimizing any release of these radionuclides to the environment.

Personnel Exposure

Personnel would be exposed to prompt radiation during the NIF yield operations. Also, after yield operations, tasks that must be performed within the NIF target bay or that involve handling of materials that have been inside the target bay during high-yield experiments would result in some radiation dose. This would not change from the No Action Alternative.

In addition, a worker dose would be incurred during routine decontamination activities. This would include handling of contaminated/activated items; disassembling them, if needed; and processing them through the decontamination systems. This dose would be largely related to the cleaning frequency, which is unchanged from the No Action Alternative (once per year). Therefore, this component of the worker dose is not expected to change for the Proposed Action.

Radiation exposure in radiologically controlled areas would be kept as low as reasonably achievable through facility and equipment design and administrative controls.

M.3.2.2 *Transport of Materials*

NIF targets would come from more than one source. Most of the targets would be provided from an onsite source, such as the LLNL Tritium Facility. The other fabrication source would be Los Alamos National Laboratory in New Mexico. Targets for the Proposed Action would include quantities of depleted uranium, highly enriched uranium, thorium-232, or weapons grade plutonium, in addition to tritium. An additional bounding scenario for the Proposed Action analysis would be the transport of one plutonium target (up to 3 grams) from its source. Post-experiment, the inner containment vessel would be transported onsite from the NIF to the Tritium Facility.

M.3.2.3 *Waste Generated During National Ignition Facility Operations*

Many of the waste streams described under the No Action Alternative would be unchanged for the Proposed Action, as they are not directly related to the proposed changes in materials used for experiments. Because fission products could be produced from some yield experiments, it is expected that there would be a small increase in LLW related to filters. Charcoal filters would be used to capture iodine isotopes, and these would need periodic, though infrequent, replacement. Other waste streams, such as the target chamber hardware or decontamination wastes, would not be expected to change because the cleaning frequency would be the same as under the No Action Alternative.

For plutonium experiments with containment, disposal of the inner containment vessel would substantially increase the low-level radioactive waste stream. The additional waste has been estimated based on 14 plutonium experiments per year: 4 with fusion yield and 10 without yield. Each inner containment vessel would occupy approximately 8.5 cubic meters of space, including void volume. Because it is expected, in most cases that the inner containment vessel would leave LLNL from the Tritium Facility, the waste would appear in the Tritium Facility (Building 331) waste stream. It is expected that only LLW would be generated as a result of using the inner containment vessel. Section M.5 provides details concerning the estimated waste streams for the Proposed Action.

M.3.2.4 *Neutron Spectrometer*

During the commissioning phase of the NIF, when full laser energy is not available, sub-ignition inertial confinement fusion experiments could be performed using targets that generate low neutron yields. Furthermore, sub-ignition experiments are planned for the NIF that would require sensitive neutron diagnostics. A neutron spectrometer capability would more accurately measure neutron yield and diagnose ignition target physics.

The Proposed Action would include the construction and operation of a neutron spectrometer to provide an accurate measure of neutron fluxes in yield experiments. Similar underground construction was done at the University of Rochester Omega laser and at the LLNL Nova laser[5]. The neutron spectrometer construction would not start before fiscal FY2008 and when completed would become part of the NIF operational facility. The eventual design of the neutron spectrometer would depend greatly on the continuing development of detector technologies and the selected imaging technology. Conservative assumptions have been made using past and existing neutron spectrometer measurement systems.

The neutron spectrometer would be contained in a shielded-concrete shaft that would extend underground outward from the NIF target chamber (Figure M.3.2.4–1). The construction of the neutron spectrometer would require excavating and installing a concrete shaft from the target chamber to a point 52 feet below the surface. The shaft would contain approximately 1 cubic meter of solid plastic scintillator (polyvinyl toluene) and would be shielded by approximately 20 tons of lead. The bottom of the shaft would be above the maximum recorded water table. The plastic scintillator, in the form of thin sheets, would be held in a rack at the bottom of the shaft. The shaft would be sealed to prevent contamination of groundwater from any leakage from the shaft or any inflow into the shaft. The design and construction of the shaft would prevent groundwater intrusion.

M.3.3 Reduced Operation Alternative

Under the Reduced Operation Alternative, the neutron spectrometer would not be constructed and there would be no experiments with plutonium; other fissile materials; fissionable materials, other than depleted uranium without yield; or lithium hydride. The operation of the NIF under the Reduced Operation Alternative would be similar to that under the No Action Alternative. The primary difference would be in the schedule of experiments, the annual yield, and tritium throughput. The tritium throughput would be reduced from 1,750 curies per year to 1,500 curies per year.

Annual yield from the NIF ignition experiments would be reduced by 33 percent under the Reduced Operation Alternative, from 1,200 megajoules per year to 800 megajoules per year. The individual experiment yields would remain at up to 20 megajoules (45 megajoules maximum credible yield), but the total number of experiments with high yield would be reduced.

[5] Nova laser was decommissioned in May 1999.

This effectively limits the number of experiments that use ignition to produce the physics data needed to support Stockpile Stewardship Campaign milestones. Some aspects of operations would be affected by the stretching of the experiment schedule. These aspects are discussed individually in this section. The differences in operating parameters among No Action Alternative, Proposed Action, and Reduced Operation Alternative are presented in Table M.3–1.

The effect of the Reduced Operation Alternative would be to stretch out experimental deliverables by an increasing amount over time in proportion to the reduced yield limits each year. Over a 10-year period, this would correspond to an approximately 3-year addition to the schedule to achieve the same deliverables for Stockpile Stewardship as compared to the No Action Alternative and Proposed Action. In the shorter term, the Reduced Operation Alternative would delay the availability of experimental data needed to optimize the NIF laser and ignition target parameters leading to the achievement of fusion ignition on the NIF. The Reduced Operation Alternative would delay the time when ignition physics data could be made available to benchmark and validate advanced computer codes used for modeling nuclear weapons behavior. The reduced annual yield would also reduce the number of weapons effects tests that would require the intense amount of neutron and x-ray radiation generated by ignition targets and used to test the radiation hardness of military systems and components.

By maintaining the full operations and support facilities staff, the facility would be in complete operational readiness, and the annual yield could be raised to either the No Action Alternative or Proposed Action level of 1,200 megajoules per year and the tritium throughput to 1,750 curies per year.

M.3.3.1 *National Ignition Facility Operations*

The laser and target area building is an environmentally controlled clean room facility housing the laser and target area systems and the integrated computer system. The majority of the building is dedicated to providing the laser power, radiation confinement and control, and all necessary system control and diagnostics. It consists of two laser bays, two optical switchyards, a target chamber in a shielded target area, target diagnostic facilities, capacitor areas, control rooms, and an operations support areas, see Figure M.1.2–1. This equipment and these operations are necessary to operate the NIF for even one experiment. Under the Reduced Operation Alternative, the equipment and operations would be the same as those described for the No Action Alternative in Section M.3.1.1.

The diagnostic building, adjacent to the target bay, houses the environmental protection systems, target receiving area, tritium processing area, and diagnostic support areas. The tritium processing system would operate by oxidizing gaseous tritium and capturing the oxidized tritiated water on molecular sieves. These operations also would be necessary for staging each experiment. These operations would be identical to those described for the No Action Alternative; however, the amount of material captured by the filters and molecular sieves would be related to the number and type of experiments. Thus, the replacement of filters and decontamination of equipment would be reduced, along with the resultant waste streams.

Facility Utility Usage

Facility operations would require the use of electrical power, water, and natural gas and the discharge of wastewater. The NIF would use electricity to operate the laser and plant equipment necessary to support basic operations. This would include operations of the HVAC system, chilled and heated water systems, lighting, and facility heating. The power used to keep the NIF at clean room conditions would be much greater than the power used by the laser in an experiment. Therefore, utility usage would not be reduced under the Reduced Operation Alternative.

The two standby diesel generators would still be maintained in readiness and, under normal conditions, would be operated only for the purpose of maintenance and testing, about 10 hours per year.

M.3.3.2 *Laser Operations*

The operating parameters established for the NIF experiments under the Reduced Operation Alternative are indicated below.

- Laser power/energy to the target: 500 terrawatts/1.8 megajoules
- Maximum design yield per experiment: 20 megajoules (maximum credible yield would be 45 megajoules)
- Annual total yield: 800 megajoules per year

Otherwise the laser operations would be the same as described under the No Action Alternative in Section M.3.1.2.

M.3.3.3 *Target Bay and Target Chamber*

The target bay consists of the following major subsystems: target chamber, target emplacement positioner, cryogenic target positioner, target diagnostic control room, support structures, environmental protection, and vacuum and other auxiliary systems. The target bay and target chamber would be operated in the same manner as described under the No Action Alternative in Section M.3.1.3.

Some aspects of the target bay and target chamber operations are scalable to the number and type of experiments conducted and, therefore, would be less under the Reduced Operation Alternative, including the following:

- Generation of radioactive air emissions, such as activated air created during high-yield experiments or a tritium release
- Generation of solid LLW from replacement of the disposable debris shields, periodic cleaning the main debris shields, and the replacement and disposal, as needed, of the main debris shields and first wall panels due to damage or age
- Use of caustic chemicals for cleaning the main debris shields and first wall panels
- Replacement of the charge-coupled discharge cameras used for target chamber diagnostics
- Replacement of filters

M.3.3.4 *National Ignition Facility Experiments*

Both indirect-drive and direct-drive experiments could be conducted on the NIF under the Reduced Operation Alternative in the manner described for the No Action Alternative in Section M.3.1.4. The series of experiments conducted on the NIF to validate system operation and evaluate weapons data would proceed as described for the No Action Alternative. The NIF would be operated as a low-hazard, radiological facility under the Reduced Operation Alternative. Only the schedule for the experiments would be changed.

Radiation Produced from Experiments

The activation of target bay structures and concrete walls by neutrons from the NIF experiments and the skyshine produced by the neutrons would be less than projected for the No Action Alternative. Therefore, worker exposure would be lower under the Reduced Operation Alternative.

Tritium

Tritium would be transported, handled, and used in the same manner as under the No Action Alternative described in Section M.3.1.4. The amount of tritium in individual targets would not be expected to change for the Reduced Operation Alternative, containing up to 5 curies each 2 curies in the capsule and up to 3 curies in the associated hardware. If direct drive were implemented, each target would contain up to 70 curies. The annual tritium throughput at the NIF would be limited to 1,500 curies per year. The frequency of delivering tritium targets would be reduced by approximately 14 percent below the No Action Alternative level. The tritium in-process inventory limit for the NIF would still total no more than 500 curies.

Particulates

The generation of particulates in the target chamber is related to the number and type of experiments. Particulate generation would be less under the Reduced Operation Alternative than that discussed under the No Action Alternative in Section M.3.1.4. As the particulate material is exposed to neutrons from yield experiments, some would become activated and converted to radioactive material. The particulates would accumulate in the target chamber until the scheduled cleanup. At that time, the radioactive particulates created in the target chamber would be transferred to the decontamination systems and waste streams. Under the No Action Alternative, the cleanup was assumed to take place on an annual basis. Under the Reduced Operation Alternative, the cleanup would take place on an 18-month cycle. For the purpose of this analysis, the impacts associated with the cleanup have been annualized and are scalable as two-thirds those of the No Action Alternative.

M.3.3.5 *Hazardous Materials*

The main nonradiological materials at the NIF would include miscellaneous solvents and cleaning chemicals, decontamination process materials, fluids in electrical equipment, and materials that are part of, or placed into, the target chamber. The use of these and other materials needed to support the NIF operations would remain the same under the Reduced Operation Alternative as under the No Action Alternative (Section M.3.1.5).

The use of cleaning agents in the decontamination processes would be less under the Reduced Operation Alternative. A roughly one-third reduction on an annual basis would be seen in the use of these agents, including phosphoric acid, nitric acid, and sodium hydroxide.

The hazardous materials associated with the power conditioning units used in support of the pre-amplified modules would remain the same under the Reduced Operation Alternative.

The NIF would use beryllium in two forms: collected solids, primarily in filters, that cannot become particulate, and material in exposed diagnostics and targets that can become particulate. The NIF would handle small quantities of beryllium in the form of targets and windows for diagnostics. This would not change on a per target basis under the Reduced Operation Alternative. It is not anticipated that there would be significant airborne exposure to the workers. This would be confirmed by air monitoring. Surface swiping would be performed to confirm that surface beryllium contamination would remain within permissible housekeeping limits for beryllium work areas (10 CFR Part 850).

The composition of targets would be the same as for the No Action Alternative. The generation of debris from the target and hohlraum deposited on the target chamber wall and debris shields would be less on an annual basis than projected for the No Action Alternative. Under the No Action Alternative, the target chamber would only be decontaminated once per year. Under the Reduced Operation Alternative, the target chamber would be decontaminated once per 18 months. The inventory of particulates in the target chamber would be reduced by one-third, on an annual basis, from that of the No Action Alternative. There will be no explosive materials stored or used at the NIF.

M.3.4 Comparison of Alternatives and Environmental Impacts

Table M.3.4–1 compares the potential environmental consequences of the Proposed Action, No Action Alternative, and Reduced Operation Alternative. The details of the environmental consequences, summarized in this table, are provided in Section M.5. The first column of the table provides information from the SSM PEIS environmental impacts. This information is provided to aid the reader in understanding the differences between the SSM PEIS and the No Action Alternative. This information is only provided as a reference. The No Action Alternative is the basis for comparison to the Proposed Action and the Reduced Operation Alternative.

Proposed Action Impacts

As indicated in the table, changes in Proposed Action impacts, as compared to the No Action Alternative impacts, would only occur in three areas. The impacts, while of concern, would not result in significant environmental consequences. The impacts would include an increased use of several hazardous and radiological materials, an increase in the generation of low-level solid radioactive waste from the use of these materials, and an increase in worker exposure.

Under the Proposed Action there would be an increase in the use of beryllium from 1.6 to 20 grams per year and the use of 125 grams of lithium hydride per year. The neutron spectrometer would also use 4,000 pounds of polyvinyl toluene and 43,000 pounds of lead for the detector. The No Action Alternative limit established for the use of beryllium would be 1.6 grams per year. The use of lithium hydride was not evaluated as part of the No Action Alternative.

Changes in the use of radiological materials under the Proposed Action would include the use of up to 3 grams of weapons grade plutonium per experiment, 100 grams of highly enriched uranium per year, 100 grams of depleted uranium per year, and 450 grams of thorium per year. The radiological materials limit established under the No Action Alternative would be 5 grams of depleted uranium per year. The use of fissile and fissionable materials, described above, is not considered under the No Action Alternative. The use of tritium would remain the same as discussed under the No Action Alternative.

The low-level solid radioactive waste would increase from 70 cubic meters per year under the No Action Alternative to 190 cubic meters per year under the Proposed Action. The 190 cubic meters is nearly 60 percent of the estimated sitewide generation of low-level radioactive waste. These levels of waste generation are within the capacity for treatment, transportation, or storage. The other waste categories numbers would remain the same as the No Action Alternative numbers.

The estimated worker exposure for the NIF operations would be 19 person-rem per year for the Proposed Action. The No Action Alternative worker exposure would be 15 person-rem per year. The Proposed Action worker exposure of 19 person-rem per year is 20 percent of the LLNL estimated total worker population dose. The latent cancer fatalities (LCFs) projected under the Proposed Action for the NIF would be 1.1×10^{-2}. The LCFs projected under the Proposed Action for LLNL would be 5.5×10^{-2}. No individual will receive more than 500 millirem per year.

Reduced Operation Alternative Impacts

The Reduced Operation Alternative impacts would be less than the No Action Alternative impacts in several areas. These would include a reduction in the use of hazardous and radiological material, a reduction in waste generation, and a decrease in worker exposure. Under the Reduced Operation Alternative, the neutron spectrometer would not be constructed and there would be no experiments with plutonium; other fissile materials; fissionable materials, other than depleted uranium; or lithium hydride.

M.4 DESCRIPTION OF THE AFFECTED ENVIRONMENT

M.4.1 Environmental Setting

Chapter 4 of the LLNL SW/SPEIS describes the environmental setting and existing conditions associated with current operations at LLNL. This information forms a baseline for evaluating the environmental impacts associated with implementing the No Action Alternative, Proposed Action, and Reduced Operation Alternative. Information from Chapter 4 of the LLNL SW/SPEIS was used as a basis for analysis of the impacts presented in Section M.5 of this appendix.